Findings on predicting future fire threats

For this section, FRAP developed a series of linked spatial metrics designed to assist in fire planning for resource protection. Fire threat, a combined index of expected fire frequency and potential fire behavior, forms the basis for this analytical approach.

Fire rotation is a measure of the expected frequency of fire, calculated for large areas using past fire size records.

Mapping expected fire frequency

Many areas of the State are burning ten to one hundred times less frequently than during the pre-settlement period.

The probability of a fire burning in a given location is a complex issue, affected by fuel conditions, weather, ignition sources, fire suppression response, and other factors. The result of this combination of factors is reflected in the fire perimeters, and can be used to calculate an area-based estimate of fire frequency called fire rotation. Fire rotation is an effective measure of relative expected intervals between fires at regional scales, where site-specific fire frequency estimates are not available (see the sidebar "Predicting fire frequency using fire rotation"). It is important to remember that lower fire rotation values indicate less time needed to burn the area and consequently indicate higher fire frequency.

The modern-era fire rotation analysis summarizes areas into the following three classes of expected fire frequency:

- High (fire rotation less than 100 years);
- Medium (fire rotation more than 100 years and less than 300 years); and
- Low (fire rotation more than 300 years).

Areas of the State with barren, urban, agriculture, and localized wildlands not under State or federal fire protection were omitted from the analysis.

Much of the southern California brush and woodland zone and some north Sierra foothill zones have the highest expected fire frequency.

Acres and percentages of fire rotation classes were calculated Statewide and are reflected in Table 2 for the area analyzed. While most of the State (54 percent) is in the Low class with expected fire rotations of 300 years or greater, 24 percent of California has rotations less than 300 years. This value increases to 30 percent when non-wildland/not mapped areas are removed.

Table 2. Area of fire rotation classes

Rotation class	Acres	Percentage of Statewide	Percentage of Mapped area
Low (>300 years)	54,242,542	54	70
Medium (100-300 years)	17,137,175	17	22
High (<100 years)	6,411,106	7	8
Non wildland/not mapped	22,209,176	22	N/A

Source: FRAP, 2002c

The map of fire rotation (see Figure 7) indicates that certain areas of the State, such as much of the southern California brush and woodland areas and some north Sierra foothill zones, are in the High fire rotation class. This indicates that these areas are the most likely to burn, while the entire southeast desert region is in the Moderate category indicating low fire likelihood. Although there are many areas that are burning roughly at, or possibly more frequently than they did under their pre-settlement regime, such as some areas of southern California chaparral and coastal sage scrub (Keeley and Fotheringham, 2001), other large areas formerly in the frequent fire regime are burning 10 to 100 times less frequently in the modern era (Martin and Sapsis, 1992; Skinner and Chang, 1996).

Pines Fire, east of Julian, San Diego County, California. Date of fire origin: July 29, 2002. CDF Photo.

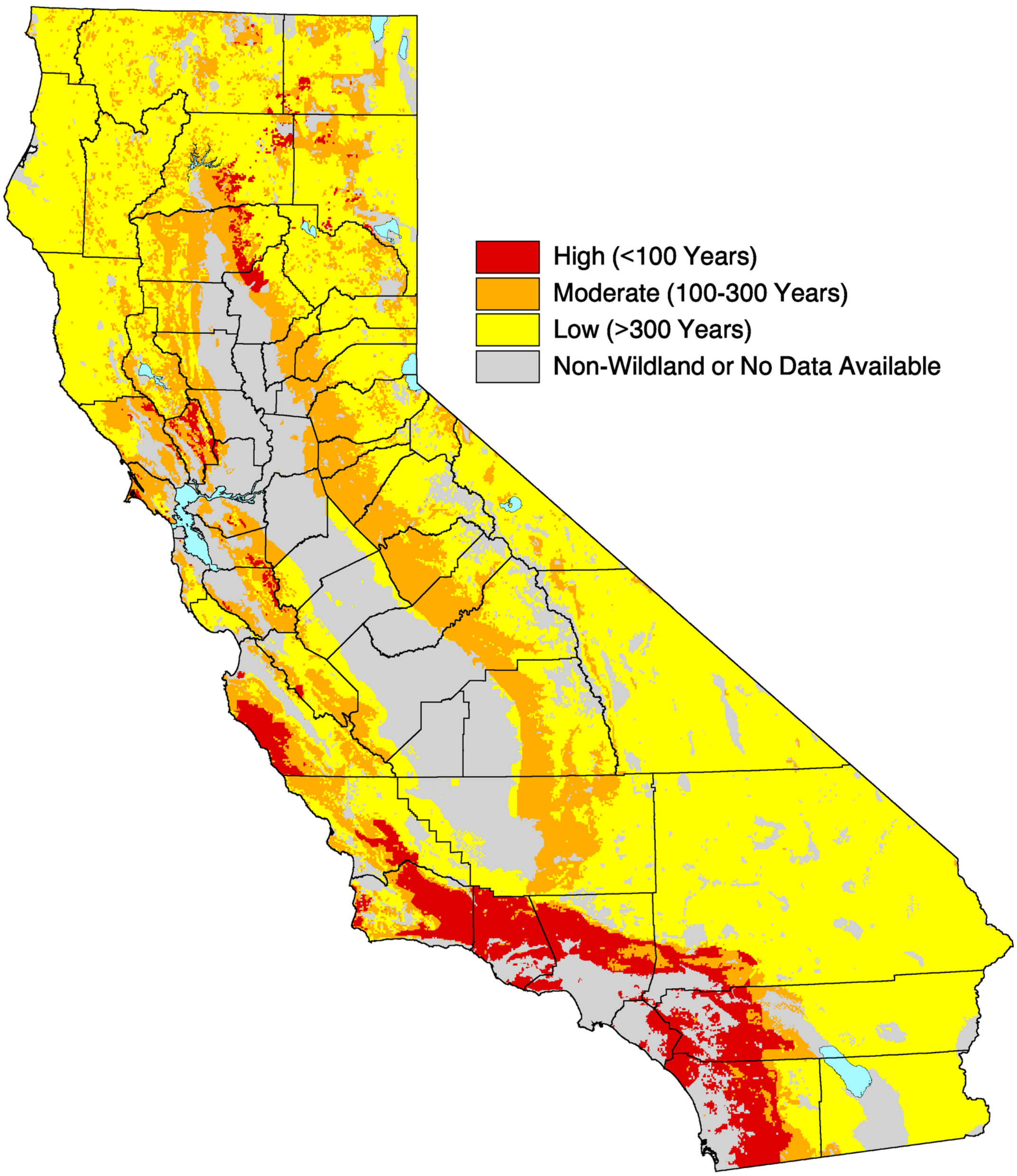
The implications of a dramatic reduction in fire frequency raises both ecological and public safety concerns, particularly where the removal of fire alters fuelbed characteristics resulting in significant increases in expected fire behavior. A dramatic example of this type of change is exemplified in the lower elevation ponderosa pine/mixed-conifer ecosystems where FRAP's calculated fire rotation for Sierra bioregion conifer under CDF protection is 618 years. The expected fire frequency under the natural fire regimes would have likely been between five and 15 years (Skinner and Chang, 1996). One example of altered fuelbed characteristics is increased amount of dry fuel per acre, that can burn more intensely once a fire has started, posing greater risk to people and damage to soil and vegetation.

Implications of a dramatic reduction in fire occurrence raise both ecological and public safety concerns.

Predicting fire frequency using fire rotation: To determine a basic index of wildfire frequency from which to base fire planning, FRAP supplemented the fire perimeter data mentioned previously with point fire records for the smaller fires not in the fire perimeter data set and calculated an area-average based estimate of fire frequency called fire rotation. Fire rotation is the number of years it would take to burn an area equal to the size of a particular land type under consideration. For instance, if a particular area is 1,000 acres, and it has burned an average of 100 acres per year, its calculated fire rotation is ten years. Separate fire rotation calculations are made for various groups of land areas that are stratified on characteristics that are assumed to affect fire frequency. Each stratum in this analysis is a particular combination of vegetation life form, bioregion, and agency responsible for fire protection services. A detailed discussion of the fire rotation analysis methods and results can be found in Estimating Expected Fire Frequency using Fire Rotation.

The complete regional and county breakdown of fire rotation data can be found at Fire Data.

Figure 7. Fire rotation classes



Source: FRAP, 2002c

Mapping potential fire behavior

As important as it is to know the expected frequency of fire in an area, it is also critical to be able to assess the likely nature of the fire should it occur. Characteristics of the fire itself—its spread rate, flame length, amount of fuel consumed, and smoke produced—are collectively referred to as "fire behavior." Fire behavior is a dominating factor in how fires are fought and with what difficulty. Fire behavior also largely defines the nature of a fire's

Physical characteristics of the fire (spread rate, flame length, amount of fuel consumed, energy release rate, etc.) are referred to as fire behavior.

effects on biological and physical resources. For example, low intensity, slow moving, understory fires are not only easily suppressed but are unlikely to kill large mature trees or cause significant changes in soil structure.

Mapping and predicting fire behavior: Fire behavior is a function of interactions between fuel characteristics, topography, and weather. In this analysis of potential fire behavior, the critical components of the fuelbed and terrain are used to predict expected fire behavior under severe fire weather conditions. The focal element in this process is the determination of fuel characteristics consistent with inputs for modeling fire behavior. Statewide mapping of surface fuel models consistent with National Fire Behavior Prediction System are key inputs. In conjunction with slope information, this system allows the prediction of fireline intensity. Fireline intensity is a measure of the rate of energy release in the flaming front of a fire. These fireline intensity outputs of fire behavior are then categorized into ranks of potential fire behavior.

This analysis uses both data and methods developed by CDF for the California Fire Plan. This analysis is an offshoot of the fuels assessment for the Sierra Nevada Ecosystem Project report (Sapsis et al., 1996). While our approach to assessing fuel hazards used potential fire behavior, it is only one method of calculating fire hazards to wildlands. It should not be confused with other assessments that utilize the word hazard to describe various components or assessments of the fire environment. See the Office of the State Fire Marshal for a comprehensive description of various hazard assessments done nationwide (CDF, 2000).

Detailed assessment of CDF's fuel mapping procedures and how these data are converted into potential fire behavior ranks can be found at Surface Fuels Maps and Data (FRAP, 2000a) and Fuel Rank Maps and Data (FRAP, 2000b), respectively.

Fifty-one percent of California is in either a high or very high potential fire behavior class.

Of the roughly 85 million acres included in this analysis, 51 percent is in either a high or very high potential fire behavior class (see Table 3). While a sizable portion of the State is either not likely to carry fire, or have only moderate fire behavior, many of these areas are very remote and burn infrequently (e.g., the entire southeast desert region of the State). Areas mapped as urban were included as having moderate potential fire behavior. The actual expected fire behavior in urbanized environments varies from none to extreme, but no data exists from which to effectively assess fuel and housing characteristics affecting fire behavior.

Many areas of moderate potential fire behavior, such as grasslands, are interspersed into areas of higher potential fire behavior and may often act as vectors for fire spread (see Figure 8). Extensive areas of Very High potential fire behavior border many areas of population centers like the Los Angeles Basin, while the western flank of the Sierra Nevada forms a continuous belt of dangerous fuels. A complete breakdown of potential fire behavior ranks by county and bioregion can be found at Fire data.

Table 3. Area of potential fire behavior

Rank	Acres	Percentage of State	Percentage of mapped area
Moderate	41,912,451	41	49
High	31,475,139	31	36
Very High	11,994,298	13	15
Not Mapped	15,582,152	15	--

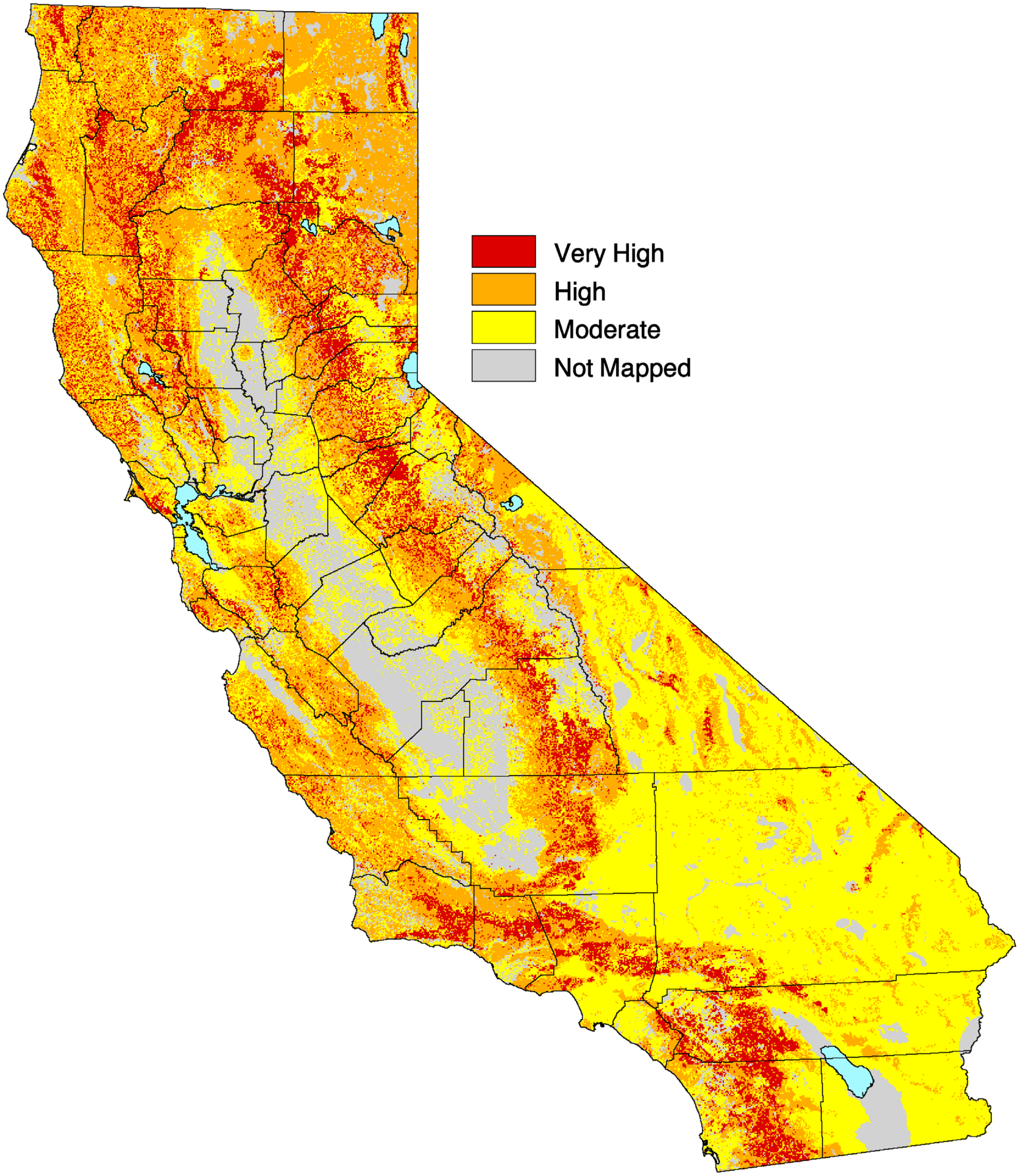
Source: FRAP, 2002d

The widespread level of dangerous fuel conditions is a result of highly productive vegetation systems accumulating fuels and/or reductions in periodic fire. As vegetation structure changes in the absence of fire, many plant communities arrange their living biomass in ways that increase the fuel availability and expected fire intensity. A prime example is mixed conifer systems that naturally existed under frequent, low-severity fires. In the absence of these understory cleansing events, live vegetation in the form of shrubs and regenerating conifers grow and increase crown fire potential over and above the changes in surface fire expected due to accumulation of downed, dead biomass.

Understory regeneration in mixed conifer: Changes in stand structure result in increasing potential fire behavior. Thousands of shade tolerant white fir and incense cedar seedlings and saplings per acre form significant “ladder” fuels, linking surface fire to fuels in the forest canopy. Changes such as these in vegetation structure often result in high intensity crown-fire in otherwise surface-fire adapted forests. Crown fire is not only fast spreading and difficult to control, but also results in high levels of severity, killing even the largest, most fire-resistant trees in the forest.

Ladder fuel conditions contributing to very high fire behavior potential in a mixed-conifer forest.

Figure 8. Potential fire behavior



Source: FRAP, 2002d

The implications of widespread areas with potential for severe fire behavior have led to many institutional programs designed to mitigate these problems. As modifying fuels constitutes the only practical means of altering potential wildfire behavior, most policies and programs are emphasizing fuel treatments. The California Fire Plan and the U.S. Department of Agriculture/U.S. Department of the

Interior National Fire Plan are both designed to provide a framework for managing fuels as a way to protect people and natural resources from damaging wildfires that result from unnaturally high levels of fuels. See Fire Risks to Assets.

Wildland fire threat

Combining the previous indices describing fire frequency and fire behavior, FRAP has developed a single assessment metric for fire called "Fire Threat."

As previously discussed, fire frequency and potential fire behavior are each classified into one of three rankings: 1) moderate; 2) high; and 3) very high. The two component scores were summed to develop a threat index ranging from 2 to 6. This threat index is then grouped into its own three level classification. Threat scores of 6 (i.e., having both the highest frequency class and highest fire behavior rank) received an extreme fire threat rank, scores of 4 or 5 received a very high threat rank; a score of 3 received a high threat rank; and a score of 1 or 2 received a moderate threat rank (see Table 4). Areas that did not support wildland fuels (e.g., open water, agriculture lands, etc.) were omitted from the calculation of fire threat. Areas with a zero value for fire rotation score but having a potential fire behavior rank were included due to many areas not calculated due to historic fire data deficiencies precluding the ability to determine fire rotation.

Wildland fire near development. CDF photo.

Table 4. Fire threat matrix based on fire rotation class and potential fire behavior rank

	Potential fire behavior		
Rotation	1 (Moderate)	2 (High)	3 (Very High)
0 or 1 (Moderate)	1 or 2 (Moderate)	3 (High)	4 (Very High)
2 (High)	3 (High)	4 (Very High)	5 (Very High)
3 (Very High)	4 (Very High)	5 (Very High)	6 (Extreme)

Source: FRAP, 2003b

Fire threat is an index of both the expected fire frequency of fire occurring and a measure of the fire's physical nature to cause impacts.

Significant fire threat is widespread throughout California, with approximately 48 percent of the State's wildland area supporting high, very high, or extreme fire threat ranks (see Table 5). While roughly one-third of the State presents a moderate fire threat, there may still be significant impacts from wildfires should they burn under extreme fire weather conditions.

Table 5. Statewide fire threat

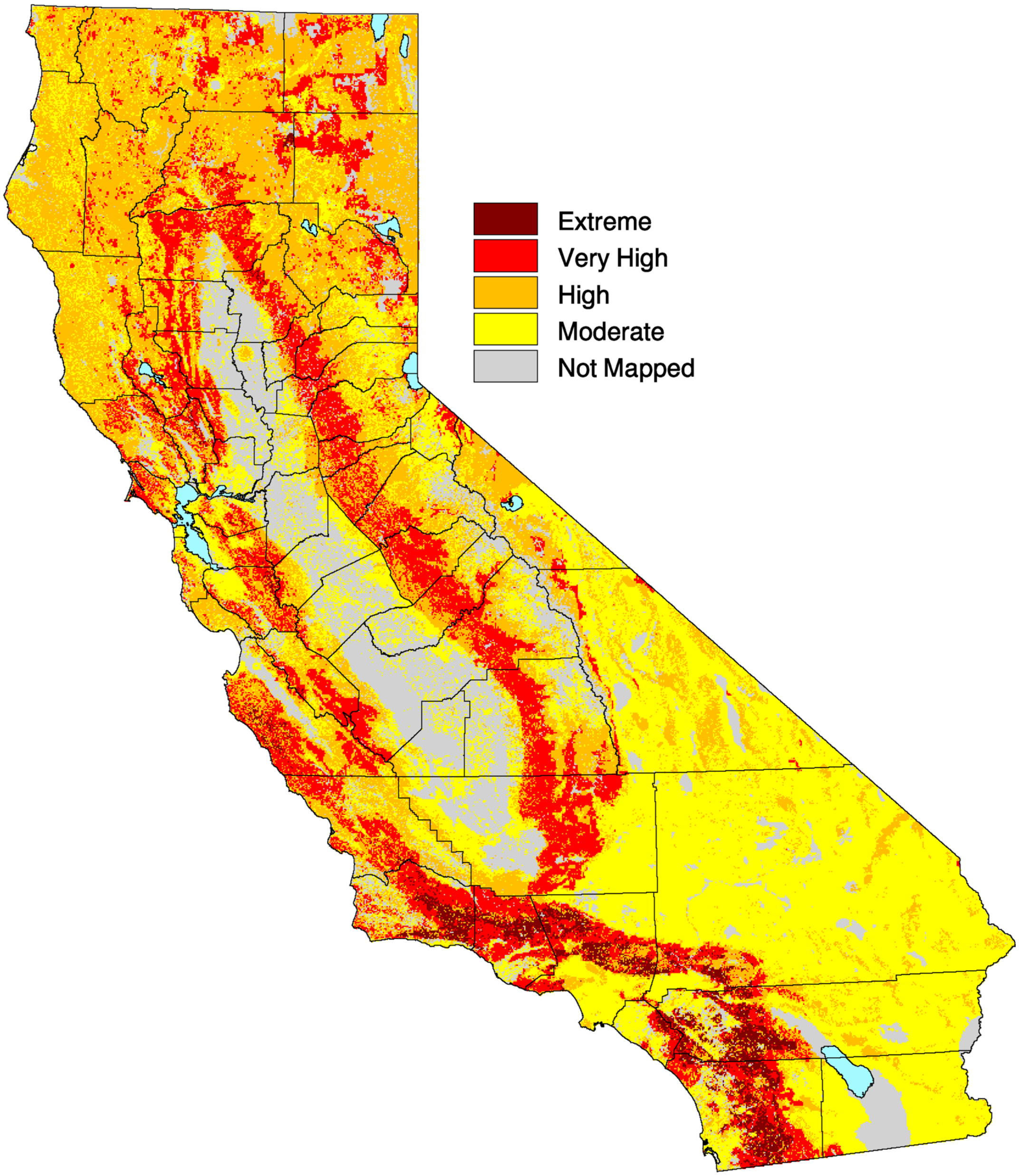
Fire threat	Acres	Percentage of State	Percentage of mapped area
Moderate	36,942,600	37	45
High	30,370,766	30	35
Very High	15,769,155	16	18
Extreme	2,249,365	2	2
Not mapped	15,582,151	15	--

Source: FRAP, 2003b

The map of fire threat suggests that areas of high threat are scattered Statewide, with large contiguous zones in southern California, the central coast, lower elevations of the Sierra Nevada, and much of the interior of northern California (see Figure 9). Fire threat is both widespread and adjacent to many areas of dense population and growth. While the components driving the threat may vary, some widespread areas like the brushlands of southern California are rated high for both expected fire frequency and fire behavior components. While of limited use in and of itself, the threat index can be used to assess potential fire impacts on various natural and community resources important to the citizens of the State. See Wildfire Risks to Assets.

A complete regional and county summary of fire threat can be found at Fire Data.

Figure 9. Threat of wildfire



Source: FRAP, 2003b

Glossary

anthropogenic: Caused by humans.

California Wildlife Habitat Relationship: California Wildlife Habitat Relationship is a state-of-the-art classification system for California's wildlife. CWHR contains life history, management, and habitat relationships information on 675 species of amphibians, reptiles, birds, and mammals known to occur in the State. CWHR products are available for purchase by anyone interested in understanding, conserving, and managing California's wildlife.

CDF: California Department of Forestry and Fire Protection.

CWHR: See **California Wildlife Habitat Relationship**.

fire behavior: The physical characteristics of a subject fire. Common fire behavior variables include rate of spread, intensity, fuel consumption, and fire type (e.g., surface vs. crown fire).

fire frequency: A broad measure of the rate of fire occurrence in a particular area. For historical analyses, fire frequency is often expressed using the fire return interval calculation, whereas in the modern-era where data on timing and size of fires are recorded, fire frequency is often best expressed using fire rotation.

fire hazard: Physical conditions of the fire environment that can cause damage; often viewed as the combined effects of slope and fuel conditions.

fire intensity: A measure of the rate of energy released in the flaming front of a fire.

fire occurrence: A single fire event taking place within a designated area.

fire regime: A measure of the general pattern of fire frequency and severity typical to a particular area or type of landscape. Regime can include other metrics of the fire, including seasonality and typical fire size, as well as a measure of the pattern of variability in characteristics.

fire return interval: A fire record based estimate of the number of years required to burn most or all of area under consideration, usually based on individual point, or small area records of fire occurrence over discrete periods of time. FRI is consequently often used when doing fire history studies from fire scar records on trees.

fire risk: Expected damage from fire to a particular asset or resource under consideration.

fire rotation: An area-based average estimate of fire frequency, calculated as the length of time necessary for an area equal to the total area of interest to burn. Fire Rotation is often applied to regionally stratified land grouping where individual fire-return intervals across the variability of the strata (i.e. the fine scale pattern of variation in timing of fires) is unknown, but detailed information on fire size is known. Hence, fire rotation is a common estimate of fire frequency during periods of recorded fire sizes.

fire severity: A measure of the effects of a fire on ecosystem components, usually the dominant vegetation, often expressed in terms of level of mortality. A broader definition includes any measure of ecosystem.

FRAP: Fire and Resource Assessment Program.

FRI: See **fire return interval**.

mean fire-return-interval: An arithmetic average of point-based measures of time between successive fires in an explicit area.

overstory: The larger, taller trees that occupy a forest area and shade young trees, hardwoods, brush, and other deciduous varieties growing beneath the larger trees (i.e., understory).

USFS: U.S. Forest Service.

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